SCANNERS AND PHOTOGRAPHY: A COMBINED FRAMEWORK

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ABSTRACT

Latest Lidar scanner technologies have great potential to contribute to construction processes by capturing accurate data in a convenient way. In particular, handheld Lidar scanners have the potential to provide real-time data from insitu buildings that are under construction or will be redesigned during construction. Focusing on the advantage of handheld Lidar scanners and photogrammetry technologies, this paper presents an integrated framework to revise digital drawings based on updated data from construction objects. The data was collected using handheld scanners for two floors of a building. Additional data was collected using terrestrial scanners including point clouds and photos in order to compare different Lidar technologies and update the data.

The findings show how handheld laser scanners differ from terrestrial scanners: efficient for updating data to assist designers to revise digital construction drawings, easy to use without high-skilled labour required, and less expensive than terrestrial scanners. The procedures of creating models from different tools, namely handheld and terrestrial Lidar scanners, are compared to evaluate the feasibility of semi-automatic data acquisition for creating Building Information Models (BIM). It was found that the framework using handheld Lidar, potentially enables designers to quickly revise drawing of complex objects. The proposed study is a step towards semi-automated modelling and drawing revision of construction objects.

Keywords: Lidar, Challenges, Digital drawings, Laser scanner, Photography

INTRODUCTION

Future trends for construction revolve around the utilisation of digital technology. There is a desire to convert all construction documentation to electronic edition compatibility. However, the possibility of acquiring accurate data from complex objects in both indoor and outdoor settings, as well as the skill to work with captured data needs to be improved for as-built documentation purposes (Giel and Issa 2011). Therefore, a tool capable of detecting objects and collecting accurate coordinates, colour and texture in a timely manner would have significant value for contractors. This tool could contribute to the flow of information and increases the quality of technical communication on construction sites.

Given the above, a procedural framework for utilisation of scanners is proposed which aims to assist contractors to utilise a chosen laser scanner and incorporate 3D Lidar point cloud data captured into a BIM. The main objectives of this paper are: 1) to implement advanced technologies to create as-built drawings; 2) to examine the feasibility of new scanners to capture data for digital drawing modelling for different purposes such as progressive monitoring during construction; and 3) to investigate the possibility of developing an integrated system to collect new information and building mature models from different tools. The originality of this paper lies in implementing a novel framework to use different scanner technologies for rich data acquisition for creating digital drawings. The presented framework enables contractors to update a BIM and use it for different purposes on the construction site.

The paper first identifies technology gaps and barriers to the automated modelling process. Second, a novel procedural framework for creating as-built drawings using scanner technology is implemented. Third, the process is put into action via applied experimentation using three competing Lidar technologies. This included comparison of terrestrial and handheld scanning technologies and experimentation with supplementary photography to improve colour and texture recognition of scanned objects. Finally, future pathways of investigation are suggested.

DIGITAL DRAWING TECHNOLOGY

The process of scanning for the purposes of real time enhanced digital drawing modelling can be divided into three main phases: 1) point cloud data acquisition (Sepasgozar et al. 2014, Sepasgozara et al. 2015); 2) photo shooting, and 3) building information modelling.

Recently, researchers have been using photogrammetry techniques to produce digital and parametric data for as-built information modelling. Photogrammetry refers to geometric information derived from photographs (Zhu and Brilakis 2009, Klein et al. 2012). However, this method has limitations (Bhatla et al. 2012, Klein, Li et al. 2012) and in particular, difficulties in extracting object points from close but wide angled situations (Klein, Li et al. 2012). This approach cannot produce the required information about the topography of irregular shapes in detail and cannot provide the details of curves and irregular shapes, whereas Lidar scanners can capture such details easily. Photogrammetry usually cannot be used independently in creating as-built models, therefore, it is not a holistic or ideal solution for capturing a progressive understanding of the actually built building (Markley et al. 2008).

A few recent studies attempted to integrate digital photogrammetry with Lidar scanners (Jeyapalan 2004, Liu et al. 2012). Lidar is a laser imaging technology that is increasingly employed for capturing scenes with millimetre to centimetre accuracy (Sepasgozar et al. 2014, Sepasgozara, Limb et al. 2015). It provides fast, accurate, comprehensive and detailed 3D data about the scanned scenes at the rate of hundreds of thousands of point measurements per second. Laser scanners collect data in the form of point clouds which make it possible to define shapes and dimensions of objects in real space, converted and represented as a collection of points in a 3D digital space (such as a BIM). However, there are two main problems for utilisation of these technologies. Firstly, the geometric information such as lines and surfaces cannot be easily extracted from the millions of data points associated with the captured object environment (Arayici 2007). Secondly, only a limited number of scanners such as terrestrial scanners (which can use LIDAR technology) are suitable for BIM (Xiong et al. 2013). Therefore, Lidar scanners have yet to mature in terms of usage with BIM. This sets up the need to examine the state-of-the-art concerning the technologies mentioned above.

RESEARCH METHOD

In order to investigate the capabilities of different advanced technologies, a combination of two data acquisition techniques, photography and Lidar scanner were adopted. Previous work shows that Lidar scanners provide dimensioning data in an accurate manner and within a short time frame (Sepasgozar, Lim et al. 2014, Sepasgozar, Lim et al. 2014, Sepasgozara, Limb et al. 2015). However, the drawback of such scanner technology is that they are not very helpful in defining objects in terms of texture and colour. In this paper, photos are collected to cover the deficiency of the previous studies by providing supplementary information. Therefore, the process of data acquisition is divided into sub-processes of ‘scanning’ and ‘shooting’.

The sub-processes of the data analysis are presented in the next section as the procedural framework consists of scanning, shooting and creating 3D models. Field experimentation using the scanner/photography technology was undertaken in a real world data capture scenario, using a sample building. A number of competing approaches were tested including: a handheld mobile scanner (HMS) which was used in conjunction with a contemporary handheld digital camera; and two stationary terrestrial Lidar scanners (TLS) with different range including a multi-station and scan station model. The feature set of the competing technologies was analysed with respect to onsite application and subsequent data conversion processes. The intention was to compare the performance of the Lidar scanners with camera combination, and their compatibility with photography approaches.

The utilized HMS included a 3D sensor system that consists of a rotating and trawling 2D Lidar and an internal measurement unit mounted on a spring mechanism. This scanner was utilised because in contrast to the stationary TLS models tested. For instance, the HMS does not need a tripod or a vehicle and skilled operator. The handheld scanner utilised an algorithm for data collection that takes advantage of recording points against a trajectory route and other reference points. The HMS was transported through a loop in the corridor of an existing building on the third and fourth floors. The area represented a lot of detail such as doors, windows and stairs. This study area was selected as it was complex enough to explore the accuracy of the different scanner technologies. The TLS options were used at two locations from less than three metres distance from the objects being measured. The maximum distance measurement and the maximum range were 50 and 1000 metres respectively for the TLS units.

PROPOSING A COMBINED PROCEDURAL FRAMEWORK

This section presents a procedural framework for acquiring data for producing construction drawings (e.g. as-built drawings). The innovative framework is called Drawing Assistance Modelling (DAM). Based on our previous work, the overall process for as-built creation is proposed consisting of scanning, processing and creating (Sepasgozar, Lim et al. 2014, Sepasgozar, Lim et al. 2014). This process is being developed as a part of an on-going study in order to create drawings that can benefit from the advantages of the Lidar technology and photography. Figure 1 shows that DAM consists of four phases as follow:

Phase I – TLS and HMS were used for data capture, data processing, polygon extraction, making volumetric models and creating initial information models. The implementation of this phase was reviewed and the challenges of implementing the procedure are discussed in the following sections. This phase refers to the process of data collection using the scanners. The data was registered and obvious noise was removed. The main elements including openings, walls, floors and ceilings were segmented in the next step. Then, the extracted elements were combined to define as-built elements. Fieldwork was conducted to assess and verify the level of accuracy obtained using the Lidar points to define as-built objects.

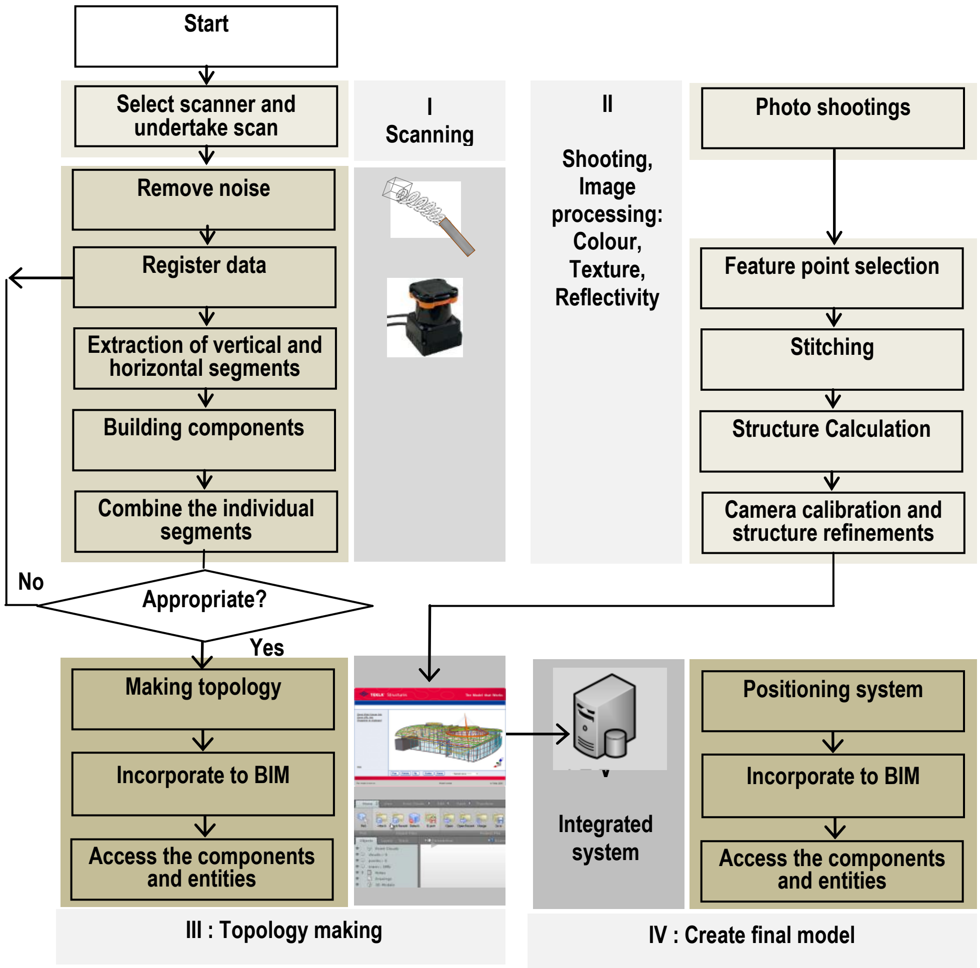

Figure 1. The developed procedure for creating drawing modelling

Phase II – A contemporary handheld digital camera was used in conjunction with the HLS technology for collecting complementary information about the texture and colour of objects. Similar functionality was also available for the Multi Station TLS as it incorporated its own on-board digital camera.

Phase III – The information collected from previous phases including point clouds and photos were used to make the topology for information modelling. In this phase all data was then incorporated to produce a rich model (for each Lidar technology).

Phase IV – The modelled objects and other information such as scheduling and positioning systems were collected in an integrated system to examine the feasibility of measuring construction progress. This part of the algorithm needs to be implemented in the second stage of the study.

CHALLENGES AND SUGGESTIONS

Experimentation via implementation of the above procedural framework allowed insights into the challenges of using the different Lidar technologies i.e. for collecting data used in as-built drawings. Particularly, it focuses on practical challenges of using scanners. Table 1 presents findings from the abovementioned field experimentation plus related specification data about both TLS models as well as the HMS and camera combination.

Table 1. Comparison matrix of Implementation of TLS, HMS and Photographs

	Item	TLS (both models)	HMS	Digital Camera
Spec	Max. Range	300 m to 1000 m	20 m	50 m
	Equipment cost	\$60,000 to \$75,000	\$25,000	\$200 to \$1000
	Portability	7 to 8 kg	510 g	500 g
Field	Operating	Careful adjustments required thus it is time consuming	No adjustments required	No adjustments required
	Skill required for operation	High	Low	Low
	Practical output accuracy	+/- 3 to 15 mm	+/- 5 to 30 mm	cm
	Spatial data speed	Real-time retrieval possible	Processing required	Manual
	Operation time	Approx. 11-30 mins	Approx. 5 mins	2 mins
	Geometry of the object (shape)	Influences the work	Strongly influences the work i.e. noise is harder to remove	Influences the work
	Weather condition	Influence the work if outdoors	Influences the work if outdoors	No influence on the work

Some of the key challenges of with respective technologies are outlined as follows:

1) There are many construction objects which must be surveyed and then selectively separated for use in the drawings. The objects vary from a large wall to fine openings to stairs. Due to the fixed setup location of the TLS technology, visibility of the intended objects is often obstructed by other objects that get in the way. For example, constant movement from people and machines throughout construction contribute to more noise in the data during the operation process, because the scanning process

takes longer than other approaches and subsequently captures more unwanted artifacts (see Table 1).

As shown in Figure 2, TLS requires a tripod to setup and then it must be moved multiple times to capture the same information that is captured via single pass of the handheld HLS scanner. Of further note, it can be seen from Table 1 that the HMS is much more portable, cost and time-efficient. Even so, Table 1 also indicates that the TLS is significantly more accurate where fine dimensional detail is required for the likes of fine grain positional or setout work. Therefore, recommended use may ultimately be dependent on the purpose and situational circumstances.

Based on the above, the field experimentation shows that a mix of TLS and HMS should be used in order to update the documentations of construction objects so it is more helpful for the drawer/draftsperson to create a mature model and easily updates the documentations for ongoing activities during construction.

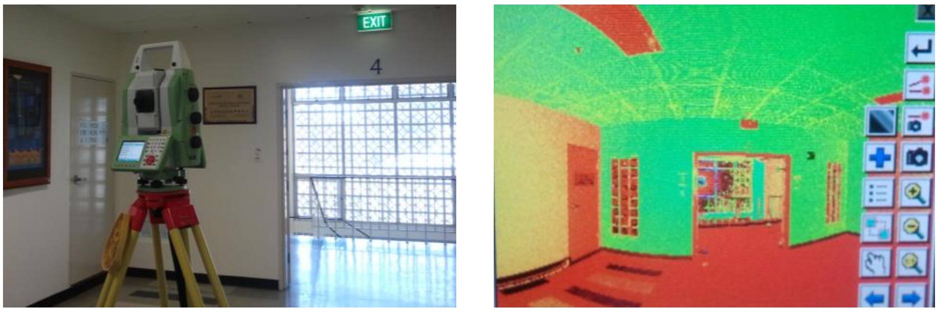

Figure 2. Collecting data from different objects such as walls and openings

2) The scanners were incapable of capturing the texture and colour of each object directly. Particularly in construction, many materials had a similar colour scheme. So, using photography as a supplementary tool can help the contractor to enrich the information in BIM by adding the information collected from photos. However this task is ostensibly a manual one and needs further research to develop an automated procedure to decrease the errors in data entry. Park et al. (2011) generated texture information of a building using a commercially available Canon camera. They showed that texture mapping of the 3D model should be done in two layers: walls; and roofs. They suggested that using the pictometry data reduces the processing time, but the accuracy would be about 1 cm.

3) Since the process of integrating Lidar with photogrammetry needs much work to be automated. Thus it is imperative that challenges and barriers for an automated process of collecting and processing data, be identified.

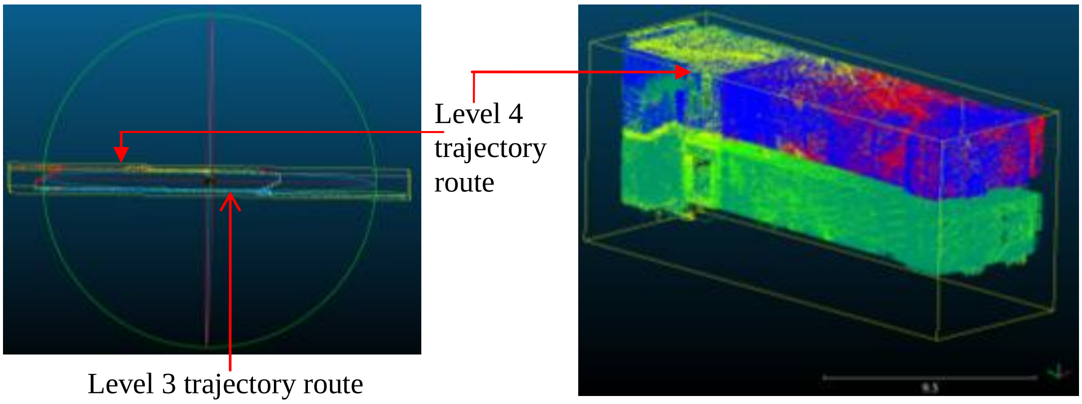

Figure 3. Trajectory of the HMS for scanning level 3 and 4.

4) Moving the TLS and making adjustments is time-consuming and not particularly cost-efficient. In contrast, the experiment showed that using HMS enabled construction engineers to capture indoor data without any setup requirements. Figure 3 shows the trajectory of HMS, which illustrates the route the scanner travelled in the indoor area of the building, and mapped inside the building. The operation time also is very quick and does not require skilled operators to capture data (see Table 1). It seems that such technology is well suited for use in construction for updating as-built documentation and drawings.

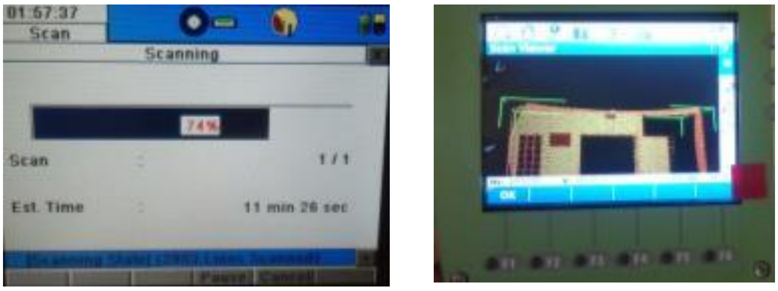

Figure 4. The scanning time and the model view

5) The scanning time for the test area (covering approximately 100 m2) was fast compared to the likes of traditional hand held measuring (such as a measuring tape). For instance, Figure 4 shows the TLS total station used only 11:26 minutes to capture a dense point cloud of the entire area but of course this relies on fast post capture processes in order to ensure true efficiencies are properly realised. The scan viewer also provides the possibility to see the scanned area during the scanning process. However, HMS cannot easily provide a view at the time of scanning. In addition, the communication between any of the tested scanners, TLS and HMS, and office computers, is not real-time. As operators need to collect data from different objects using different scanners and a camera, it is a concern how they would be able to communicate in terms of time and

compatibility. In addition, a Wi-Fi system is also required to make the real-time communication possible. As the data needs post-processing, it was not possible to directly transfer all data to BIM.

CONCLUSION

The aim of this paper was to investigate the feasibility of using different scanners and photography in order to develop a framework for rich digital modelling. The data from the experiments with different types of Lidar scanners was analysed in order to examine the feasibility of creating drawings of as-built construction. The framework presented in this paper is different to previous studies as it shows some possibility for recognising texture and colour for each object that are required to complete digital drawing modelling. Object dimensions were cross-validated using different Lidar scanners and manual survey measurements with photography. The modelling results provide accuracy to millimetre level.

Field experimentation shows that a potentially cost-efficient way of creating a BIM from scanned site data is to use HMS with a simple point-and-shoot camera, because a photo can capture the colour and visual texture of the object which cannot be achieved by Lidar scanner only. This of course will still require off-site processing of the two data sources to assign colours and texture to the captured objects which will have a secondary impact on cost effectiveness. It is also less applicable where high level dimensional accuracy is required.

The presented framework is a valuable tool that assists practitioners to create digital drawing models in BIM. However, there is much work to be done to implement this framework in different fields and to develop a semi-automated drawing tool. There are many different complex objects in construction so future studies should examine different objects in terms of complexity, size, volume, location and in extreme weather conditions in construction.

REFERENCES

Arayici, Y. (2007). "An Approach for Real World Data Modelling with the 3D Terrestrial Laser Scanner for Built Environment." *Automation in Construction* 16(6): 816-829.

Bhatla, A., S. Y. Choe, O. Fierro and F. Leite (2012). "Evaluation of Accuracy of As-Built 3D Modeling from Photos Taken by Handheld Digital Cameras." *Automation in Construction* 28(0): 116-127.

Giel, B. and R. R. A. Issa (2011). Using Laser Scanning to Access the Accuracy of As-Built BIM. *Computing in Civil Engineering (2011)*: 665-672.

Jeyapalan, K. (2004). "Mobile digital cameras for as-built surveys of roadside features." *Photogrammetric engineering and remote sensing* 70(3): 301-312.

Klein, L., N. Li and B. Becerik-Gerber (2012). "Imaged-Based Verification of As-Built Documentation of Operational Buildings." *Automation in Construction* 21(0): 161-171.

Liu, X., M. Eybpoosh and B. Akinci (2012). Developing As-Built Building Information Model Using Construction Process History Captured by a Laser Scanner and a Camera. *Construction Research Congress 2012*: 1232-1241.

Markley, J. D., J. R. Stutzman and E. N. Harris (2008). *Hybridization of photogrammetry and laser scanning technology for as-built 3D CAD models*. Aerospace Conference, 2008 IEEE, IEEE.

Park, H., M. Salah and S. Lim (2011). "Accuracy of 3D models derived from aerial laser scanning and aerial ortho-imagery." *Survey Review* 43(320): 109-122.

Sepasgozar, S. M., S. Lim and S. Shirowzhan (2014). *Implementation of Rapid As-built Building Information Modeling Using Mobile LiDAR*. Construction Research Congress 2014, Construction in a Global Network, ASCE.

Sepasgozar, S. M. E., S. Lim, S. Shirowzhan and Y. M. Kim (2014). Implementation of As-Built Information Modelling Using Mobile and Terrestrial Lidar Systems. *The 31st International Symposium on Automation and Robotics in Construction and Mining (ISARC 2014)*. Sydney, IAARC.

Sepasgozara, S., S. Limb, S. Shirowzhanc, Y. Kimd and Z. M. Nadoushanie (2015). *Utilisation of a New Terrestrial Scanner for Reconstruction of As-built Models: A Comparative Study*. ISARC. Proceedings of the International Symposium on Automation and Robotics in Construction, Vilnius Gediminas Technical University, Department of Construction Economics & Property.

Xiong, X., A. Adan, B. Akinci and D. Huber (2013). "Automatic creation of semantically rich 3D building models from laser scanner data." *Automation in Construction* 31(0): 325-337.

Zhu, Z. and I. Brilakis (2009). "Comparison of Optical Sensor-Based Spatial Data Collection Techniques for Civil Infrastructure Modeling." *Journal of Computing in Civil Engineering* 23(3): 170-177.